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ABSTRACT

Noting that librarians have long debated whether specific library functions may, or should, be scientifically examined, or whether they constitute an art not susceptible to scientific study, this paper reviews and critiques attempts to develop models of library material selection using the theories and methods of scientific investigation. First, the nature of scientific theory and its application to research methods are reviewed, and three levels of adequacy, descriptive, explanatory, and predictive, are discussed with illustrative examples. Several published models of the selection decision for acquisition are examined in terms of their theoretical adequacy, and the nature of theories describing potentially optimal practices instead of existing methods is examined. It is concluded that much of the research which has been done in book selection does not achieve any of the levels of adequacy described in this paper, and the hope is expressed that researchers will examine the nature of scientific theories and the criteria by which they are judged so that future work may be more scientific, and thus more productive. (29 footnotes). (Author/EW)

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Theoretical Adequacy and the Scientific Study of
Materials Selection

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ABSTRACT

Librarians have long debated whether specific library functions may or should be scientifically examined or whether they constitute an art not susceptible to scientific study. We review the nature of a scientific theory, its application to research methods, and discuss descriptive, explanatory, and predictive adequacy, providing illustrative examples. Several published models of the selection decision for acquisition are examined in terms of their theoretical adequacy. The nature of theories describing potentially optimal practices instead of existing methods is examined.

INTRODUCTION

Both practitioners and academicians have tried to understand how successful libraries and librarians function, so that other, less successful libraries or librarians might improve, as well as for the intellectual joy of understanding information acquisition, storage, and delivery systems. Although many feel that librarianship is largely an art, others over the past several decades have applied scientific methodologies to studies of library functions.

The nature of scientific explanation is often misunderstood by those who think of science as merely dissecting

animals or studying rocks [1 — 5]. Science is a way of thinking and of explaining facts [6]. Different types of explanation of specific library functions have been offered by both librarians and scholars, ranging from those completely ignoring scientific principles to those attempting to utilize scientific tools and methods. The basic nature of a scientific theory is presented below, as well as criteria by which we may determine the adequacy of a scientific model.

THEORIES

A scientific theory may be thought of as a set of statements in a precise language which makes claims about its characteristics at a fixed moment, such as the contents of a library collection yesterday, the information needs of a community of patrons today, or a similar system state. For example, the Bradford model makes quantitative claims concerning the distribution of articles in journals [7]. It provides an empirically tested law, offering an accurate description of the distribution of articles in journals beyond those originally studied by Bradford. Explanations as to why the law describes this distribution have been proposed.

Norman Campbell, a physicist, has suggested that a theory is composed of a set of hypotheses combined with a dictionary [8]. The hypotheses represent rules, statements, or variables independent of pragmatic concerns. The dictionary, on the other hand, relates the hypotheses to reality and gives them meaning.

This is analogous to a language whose syntax defines the set of acceptable or grammatical statements and whose semantics provide a meaning corresponding to each syntactically correct statement. Theories may be stated without providing both a set of hypotheses and a dictionary, but any theory may be defined within these structures. A set of procedures or a policy containing them, with an explanation of how to use the procedures, constitutes a theory, as suggested by Campbell. Thus, we will speak of procedures, policies, models, and theories as being synonymous for our purposes.

Chomsky suggests that theories may approach several levels of adequacy [9,10]. Presumably, theories approaching a higher level of adequacy are in some senses "better" than those approaching only a lower level of adequacy. The most basic level, descriptive adequacy, is approached when a theory describes real world actions or states for the universe of data from which it was developed. A descriptively adequate theory of book selection must have:

- i) a technique for representing information available before selecting the book.
- ii) a function to place any book into the set of books to be purchased or the set of books to be rejected.

As an example, let us hypothesize a library that selects 4 books with 315, 219, 355, and 129 pages, respectively, each having the subject label "art," while rejecting 3 books with 188, 314, and 310 pages with the subject label "science." Its

selection policy could be stated as "select those books with odd numbers of pages and reject those with even numbers of pages." This policy describes the results of selection decisions at this library and is descriptively adequate, but neither provides a rational justification for the policy nor could be generalized to other collections.

It is well known that a curve may be perfectly fitted mathematically to any set of points in a conceptual space. This curve or function may perfectly describe data, thus achieving descriptive adequacy, but not explain anything. However, a descriptively adequate theory is probably better than no theory at all.

Another level of theoretical performance is explanatory adequacy which is approached when a theory offers an explanation of why the data has those characteristics observed in experimental situations. Theories which approach explanatory adequacy usually make explicit relationships between variable attributes in the data set, thus showing causation [11]. An explanatorily adequate theory of book selection must have a

- i) technique for representing information available before selecting the book.
- ii) a function to place any book into the set of books to be purchased or the set of books to be rejected.
- iii) deterministic or probabilistic explanation relating the set of books and the result sets of the function (ii) above.

Continuing with the hypothetical library described above, we might propose that the library selects books with the subject label "art" and rejects those with the subject label "science." The explanation for this rule might be that this is a special library associated with a university art department and that special libraries are likely to select books dealing with the function of the parent organization and to not select books on other topics. Thus we have a theory that can both describe the actual selection policy and provide an explanation of the policy.

A predictively adequate theory not only describes the data from which it was developed but makes accurate predictions about other data. If the library with the policy described above were to now select a book on science, the theory we just suggested, "Select books with the subject label 'art' and reject those with the subject label 'science,'" could be shown to have failed to achieve predictive adequacy.

More formally, we must require that a selection theory have

- i) an enumeration of the class $B_1, B_2, \dots$ of possible books.
- ii) an enumeration of the class $S_1, S_2, \dots$ of possible selection functions, that is, all possible selection policies.

iii) a specification of a function f such that $SB_{f(i)}$ is the classification of the set of possible books into sets labeled "selected" or "rejected" by selection function S_i , that is, the selection decision made by selection policy i .

TESTING A THEORY

To determine descriptive or predictive adequacy, it is necessary to test, or analyze the measurable results of a theory. To test a theory, we may add one requirement to the above list:

iv) specification of a ranking function r such that $r(i)$ is associated with $SB_{f(i)}$ as its value.

Given this condition, we have a function r which may be used to rank selection functions, allowing one to argue that one selection function is better than another.

Following one interpretation of the works of Sir Karl Popper [12], theories are considered to be disconfirmable but not confirmable [13,14]. Popper notes in [15] that "Every genuine test of a theory is an attempt to falsify it, or to refute it." Thus, the statement "All acquisitions librarians are exciting" may be disconfirmed by locating a single non-exciting acquisitions librarian. On the other hand, one can't find enough exciting acquisitions librarians to prove that all acquisitions librarians are exciting; they merely corroborate, or provide evidence supporting the theory.

This represents the conventional interpretation of Popper. Popper himself, as well as some of his followers, have argued that, because one can never argue that an experiment conclusively proves something, one can never perform an experiment which would absolutely falsify a theory [16, 17].

Clark Glymour has developed a theory of confirmation based on Bayesian notions of probability [18]. Given our current level of support for a theory, known as prior evidence, we may accumulate new support for (or against) the theory, and integrate this new evidence with the prior support to compute the current level of confidence we should hold in a theory.

MODELS OF SELECTION

We now examine three models of the selection decision process. All three are helpful as they can assist a librarian in making the decision. By using the levels of theoretical adequacy described above, we can compare the scientific suitability of the models or procedures.

The first model, based upon the procedures in [19], suggests that works being considered for acquisition be assigned points based upon subject, intellectual content, potential use, relation to collection, bibliographic considerations, and language. Subjective criteria are given for first, second, and third priority items for each of the 6 categories; a bibliographer subjectively assigns points from a table based upon his or her opinion of the degree to which the book meets the

criteria listed in the table. Points are summed; books with 67 to 100 points are first priority books, those with 34 to 66 points second priority, and the remaining books are third priority. This provides a rough ranking of the suitability of books for the collection. This may be useful as a guide for selection.

One may argue that this theory only roughly approaches descriptive adequacy. It fails to provide objective criteria by which the policy could be tested against the works selected and rejected by a given library. Books are not identified as "should be selected" or "should be rejected." The point scheme does enable the selector to classify books into different priority levels, simplifying the selection process; however, this is describing in only the loosest ways the selection decision. This procedure also achieves a level of predictive adequacy because of the inexactness of the model and the resulting difficulty in arguing against it.

The developers of this procedure feel that "subjective judgments...cannot be eliminated from the selection process. Herein lies the art of selection." Given these statements, the developers of this model might argue that one cannot develop a scientific model of book selection.

Another study [20] develops a weighting formula with variables "weighted according to their impact in making the final decision." The resulting weight can be interpreted as

recommending selection if an appropriate threshold is exceeded. The selection criterion function is

$$\frac{\sum x}{\sum y} + P > V,$$

where $\sum x$ and $\sum y$ represent the sums of a series of individual features, P denotes a "Power factor" representing the political clout of the requester, and V a variable set to 17 for purchases and 1 for donations or exchanges. The individual variables incorporated into $\sum x$ and $\sum y$ are largely objective (faculty request, needed for reserve room, in the collection, available through interlibrary loan) although a few are subjective (review "tone," selector's opinion of the judgment of the requester). The subjective features, if consistently used, are not intrinsically unscientific; a system may be able to compensate for human biases such as consistent overestimation as well as consistency of judgment itself. Unlike the first study, a binary selection recommendation is made to select or reject a book. This makes the theory testable.

This theory approaches descriptive adequacy, in that it can predict with some accuracy the selection decisions from which the weights were developed. It does not achieve the level of explanatory adequacy as there is no explanation why the decision function takes the specific form it does and why the constants are assigned their present values. Predictive adequacy is approached; the function was tested against collections in four

libraries. "However, no absolute conclusions could be drawn" leading to a general "hypothesis for all academic libraries" [21]

A model of the selection process has been developed based upon economic and statistical decision theoretic considerations [22]. The model attempts to minimize the cost of book selection; models having more than one objective are described in [23]. A book should be selected if the costs associated with selecting and acquiring a book are less than the costs associated with rejecting it, or $C_S < C_R$, where C_S and C_R are the costs associated with selecting or rejecting a book. Because these costs may not be known before making the selection decision, we may modify our rule to suggest that a book should be selected if the expected cost of selecting it is less than the expected cost of rejecting it. This may be expressed as

$$\Pr(G|f)C_{S,G} + \Pr(B|f)C_{S,B} < \Pr(B|f)C_{R,B} + \Pr(G|f)C_{R,G},$$

where the left hand side of this expression represents the expected cost of selecting a book with feature f , while the right hand side represents the expected cost of rejecting a book, where S and R represent selection or rejection, as above, G and B represent a binary "Good" or "Bad" worth of a book, and $\Pr(x|y)$ denotes the probability of x given y .

We may now suggest a new rule, obtained through algebraic modification of the above expressions:

$$\frac{\Pr(G|f)}{\Pr(B|f)} > \frac{C_{S,B} - C_{R,B}}{C_{R,G} - C_{S,G}} = C.$$

C represents a cost constant. If we are unable to estimate the cost constant C or its components (and most library school students asked have expressed an inability to estimate them), we might rank the books in order of $\text{Pr}(G|f)/\text{Pr}(B|f)$. Books are selected in order of the descending value of this function until the decision is made to stop; this point is presumably at the point near where $\text{Pr}(G|f)/\text{Pr}(B|f) = C$.

By taking advantage of Bayes rule, and if we only wish to rank books for selection, we may modify our ranking function to

$$\frac{\text{Pr}(f|G)}{\text{Pr}(f|B)} > C.$$

If we assume binary features that are statistically independent, our retrieval function may be modified to

$$\sum_{i=1}^n f_i \frac{p_i/(1-p_i)}{q_i/(1-q_i)}$$

where n represents the total number of distinct features, p_i the probability a good book has binary feature i present (or has a value 1 assigned to it), q_i represents the probability a bad book has a 1 as the value for feature i, and the value (0 or 1) of the i^{th} feature is denoted as f_i .

The variable p_i may be estimated as follows [24]:

$$p_i = \frac{W_i + w_i}{N_i + n_i},$$

where w_i represents the number of documents selected with feature i , n_i represents the number of documents selected, W_i is

computed as the expected value of p_i before selecting any documents multiplied by N_i , while N_i represents the number of conceptual books selected upon which the W_i estimate is based. W_i / N_i may be seen as representing our prior estimate of p_i , while $(W_i + w_i) / (N_i + n_i)$ represents our posterior knowledge, the knowledge gained as a result of feedback concerning the quality of previously made selection decisions. Parameter q_i is similarly defined, with variables $\bar{W}_i$, $\bar{N}_i$, $\bar{w}_i$, and $\bar{n}_i$, with the variables defined over the set of books rejected instead of over the books selected.

If the assumptions of this model are met, the model will approach descriptive and predictive adequacy because a system based upon the model learns the proper parameter values through feedback. However, assumptions of statistical independence of features, for example, are obviously false. The degree to which these simplifying assumptions decrease model performance is discussed more extensively in [25,26]. The model does achieve explanatory adequacy through virtue of its derivation from the economic rule: select a book only if the cost of doing so is less than the cost of not doing so.

One of the advantages of using a formal model such as this one is that it may take advantage of research performed on other models with feature distributions and assumptions identical to the model of interest. Cover reports that for an average procedure classifying cases into one of two classes with n binary features, such as in the decision theoretic model proposed above,

one only needs about $2n$ training items, on the average [27]. If a decision function had available 5000 features, such as subject headings, there are 2^{5000} different possible combinations of features. Cover's results suggest that we do not need 2^{5000} selected and rejected books with which to train our decision function: we only need 10000, a reasonable number for many automated libraries. Thus, we can see the tradeoffs between increasing the number of features for our classifier and the number of books available with which to train the classifier.

MODELING NON-EXISTENT SYSTEMS

One may also develop models based upon goals not currently held by existing organizations. Such a model may prove useful in making explicit the operation of a system or in studying the similarities between it and other models.

For example, the performance of a system of highways being considered for construction may be optimized for accident-free driving rather than for drivers who are expected to occasionally have automobile accidents. By ignoring rare accidents which would probably vary little with different highway routings, the models would be simplified and, more importantly, the major variables affecting highway routings would be made explicit, leading to greater understanding of the routing process.

One can design models for library acquisitions based upon somewhat unrealistic goals not currently held by existing

libraries. One such goal, for example, would be to maximize the information and diversity in a library collection. Let us assume that each occurrence of a subject indicating feature, such as an LC subject heading, indicates that a book has a single unit of information about the subject. This is an unrealistic assumption but making it allows us to develop an interesting model. If the sacrifice associated with making the assumption is considered too great, a more realistic, but possibly less intelligible model may be developed.

We may maximize the information, and thus the diversity of subjects in the library, using an alternate definition of information to that provided by Shannon [28,29], selecting books so that

$$H = \frac{1}{r} \log \frac{r!}{r_1! r_2! \dots r_n!}$$

is maximized. The variable r represents the number of books in the library, r_i denotes the number of books with the i^{th} feature, and n denotes the number of subjects. Developing such a model may lead to worthwhile discussions about model assumptions, such as whether the goal of a library is to be maximally informative or whether the occurrence of a subject heading can be thought of as representing the presence of a single unit of information in the book.

SUMMARY

Scientific research is considered by many to be the proper form research should take. A theory should be developed and then tested, if testable. Theories which offer descriptive adequacy are good, those offering explanatory adequacy are better, and those offering predictive and explanatory adequacy best.

While some research in book selection is based, in whole or part, on scientific reasoning, it is not unusual to find published research failing to achieve any of the levels of adequacy described above. It is not the purpose of this article to chastise those who have performed "unscientifically" in the past, either because they believe the field to be an art or due to other reasons. It is hoped that by examining the nature of scientific theories and criteria by which they may be judged, future work may be more scientific and thus more productive.

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